Fiber optics discussion

Introduction

Giacintec continued the geotechnics business of Company MCE when MCE went out of business in 2006. The target, at that time was mainly sensors and telemetry for nuclear power plants and bridges. Meeting south Koreans in Paris in 2006 accelerated the process. Giacintec was having expertise in tilts sensors, displacement sensors and telemetry, Korean company GMG was offering beacons using tilt, displacement and telemetry. We naturally became representative of GMG. 2007, Prof Chang visited Paris for meeting with our customers, today called IFSTTAR, CEREMA, EDF, ANDRA, Total and others.

At that time, Prof Chang from Kumoh Institute and President of GMG explained he was developing other solutions based on fiber optics and this since 2000. Giacintec started fiber optics representation based on the fact GMG was developing solutions and fiber lines for geotechnics and was using the data logger systems selected on the market worldwide. Today we sold solutions or parts of solutions to EDF, Andra, IFSTTAR, CEREMA, Military companies and EGIS.

Background

France does not recognize expertise until testing and validating solutions. French engineers, for fiber optics, are mostly issued from telecom and focuses on data transmission and for measurements on FBG (Bragg networks). Unfortunately, geotechnics applications are mostly on large surfaces or long linear where FBG does not make any sense. To achieve measurements and as a consequence monitoring, choice remains Brillouin and Raman technics.

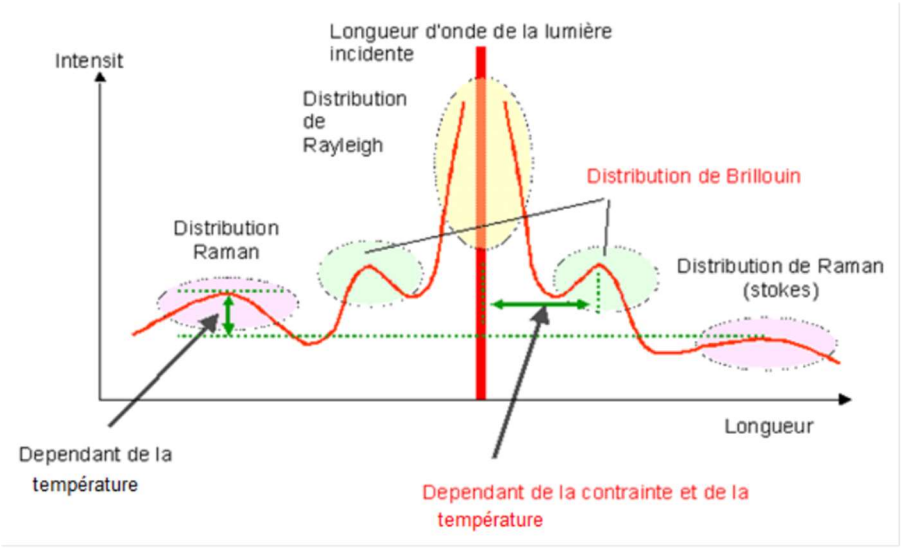
What are Brillouin and Raman methods?

When sending a light pulse in a fiber optic, the strength and or temperature, modify the light all along the fiber. The impact between the core in silica and its envelope in different silica can be measured for Brillouin as a frequency shift and for Raman as an amplitude difference. Retro diffusion provides these differences and, knowing the flight speed of the light, gives the location of phenomenon. From there, it is possible to measure strength and temperatures all along a fiber optic and to determine where the measurements are performed.

This is basically what can be done but from theory to real world there is a big gap, we will consider what can be done and how.

One has to keep in mind measurements can only be done if a sensing element exists. Processing signal for bragg networks Brillouin and Raman technics is essential but has sense only if there is a sensor.

The incident light wave length Rayleigh distribution is used as a reference. Brillouin distribution is the frequency shift and depends upon strength and temperatures. Raman distribution is the variation of amplitude and depends upon temperatures.



The light pulse is travelling all along the fiber scattering, at each point where a phenomenon occurs, will cause the frequency and amplitude drift that will be measured.

Therefore, knowing flight time of the light pulse allows to calculate the location where phenomenon occurs.

To achieve a consistent measurement needs to be careful. Brillouin method gives both strength and temperature on same fiber optic line. To separate both measurements, one need to use a fiber subjected to strength and a fiber not subjected to strength.

The fiber subjected to strength needs a pre strength to create a known strength reference and avoid errors. If the fiber is coated with silicone or other material, in the lab, Lorentzian motion will be clean but not significant. Reason why is to offer a real zero or reference, the fiber must be pre-strength. Sheathing the fiber with a metal structure will offer a real reference, enhancing the sensitivity and avoiding zero fluctuations with whatever strength unexpected and with no relation with measurement that could occur.

On another hand, measuring temperature with Brillouin method needs no strength at all, the fiber is then placed loose in a tube.

To Compensate temperature errors of the signal providing strength a double line of fiber will be used or, if the data logger operate in loop mode, one way for strength return for temperature.

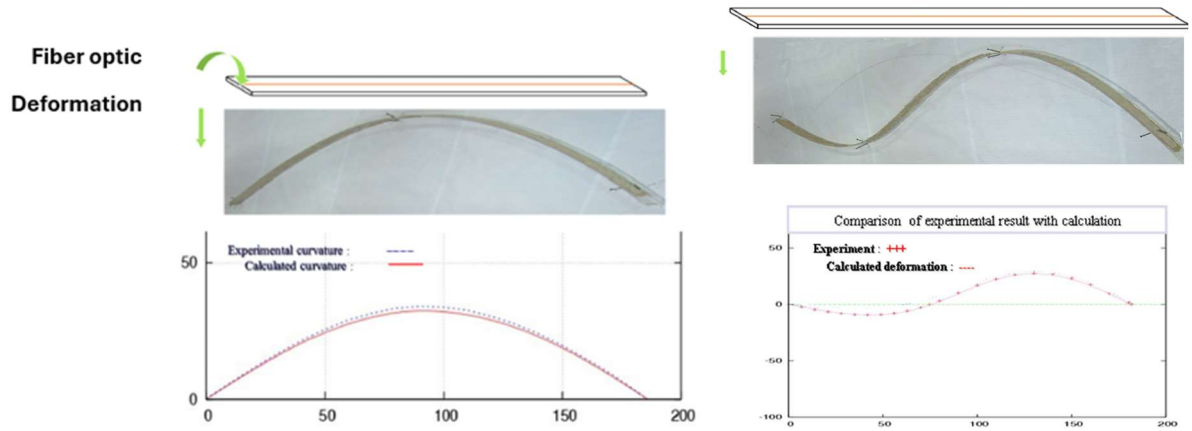
Considering Raman, measuring only temperatures, if two data loggers are used, one Brillouin and one Raman, compensation will be made easily.

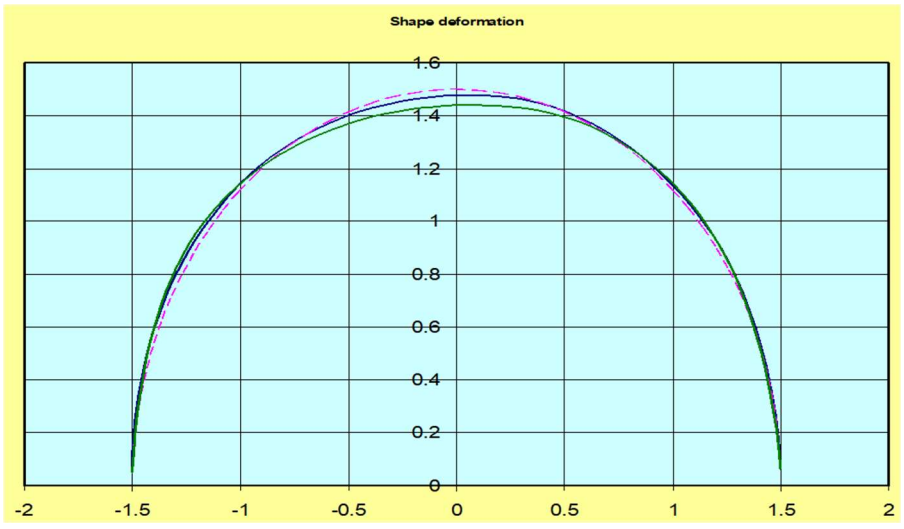
Fibers arrangements

If strength can be measured and located, one can easily understand some other parameters can be determined from there.

Thinking of pressure, vibrations or displacements sound evident as strength applied on a surface will provide load and or pressure and strength variation related to time will provide pressure.

Displacement can be calculated from deformation.

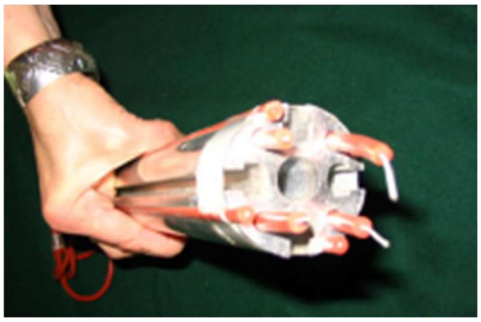


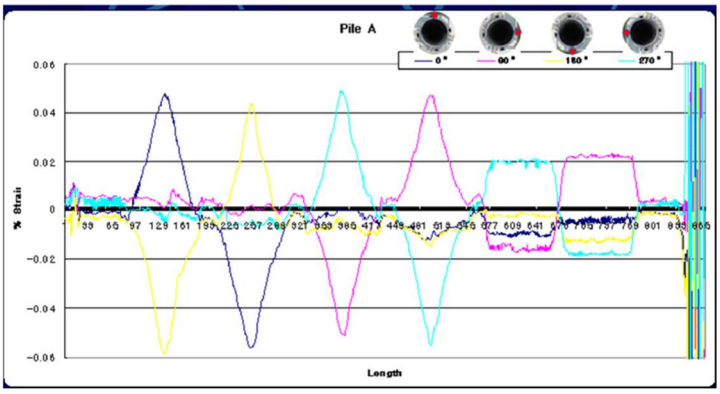


for instance settlement

When it comes to determine the sense of application of the load, the fiber optics may be assembled as an inclinometer.

On a tube, fiber optics lines are implemented perpendicular to a section and on the edge at 90 degrees angular one from the other. On each section of the tube, 4 strengths will be measured providing 4 measurement that will tell when corelated the sense of application of the load.



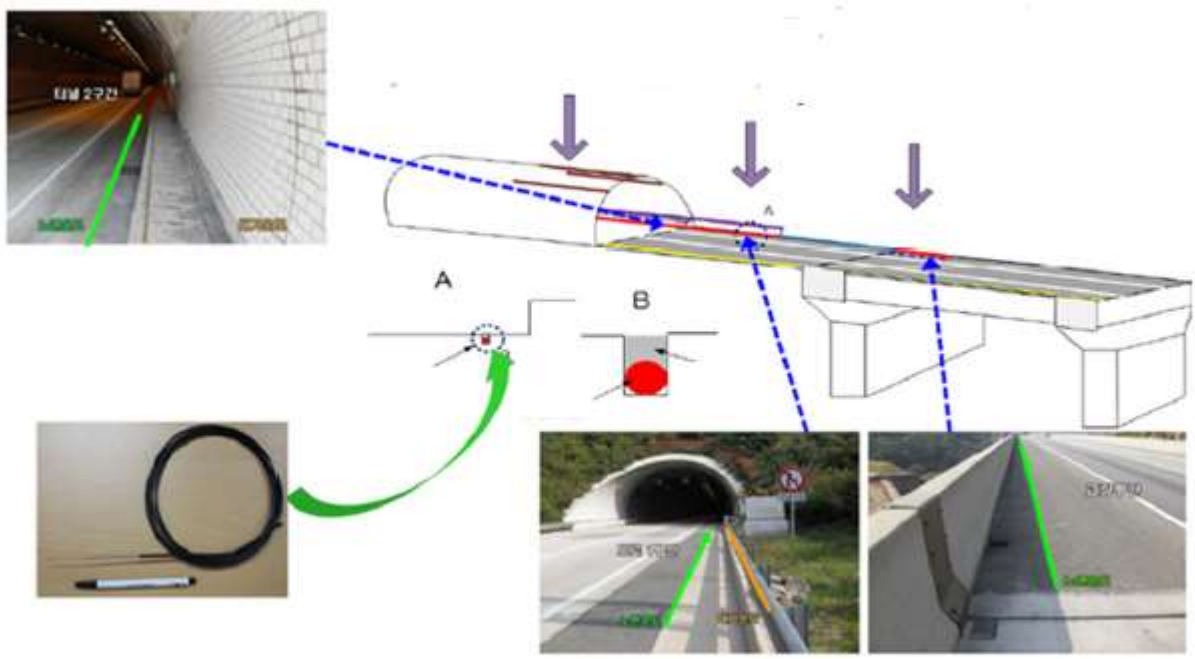


This makes available inclinometers all along the inside of a drilling as long as it is tightly maintain in the hole. Kilometers of inclinometers chain can therefore be achieve either in a drilling or along of a tunnel.

From temperature measurements

If strength can lead to several parameters, temperature may represent also a good opportunity to solve problems.

Temperature measurement accuracy are good enough to make a difference in between zero and negative values. Negative values under zero under pavement can inform on icing location.



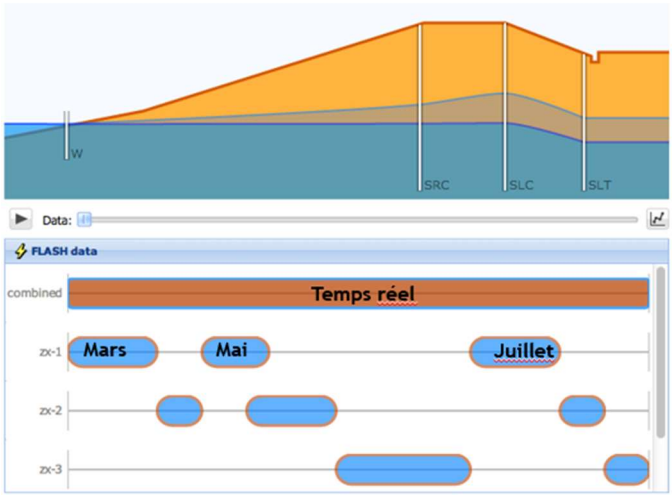
At the other end fiber optics will sense increases in temperature and warn quickly on burning start. Fire detection and location may be added simply to a fiber optic instrumentation.

When thinking about fiber optic arrangement, one can think of a difference of temperature from dry environment to wet.

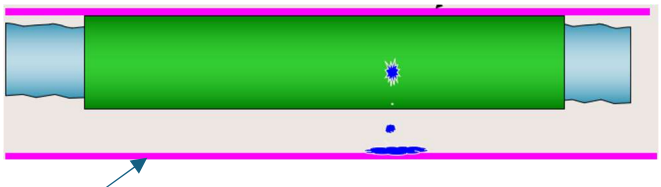
Water level measurements are possible due to temperature measurements. Spatial accuracy will not be a problem if increasing fiber optic length on small portions of tubing.

Implementing the fiber optic length as a spiral around a tube will reduce special accuracy to few spiral and, therefore provide an interesting water level measurement.

Then the fiber optic will be used as piezometer. Coupled to an inclinometer length, this assembly can fit dykes and inform on the movement inside the structure in same time than on water flow. This will lead to possible detections and locations of water flow in the structure and makes possible internal erosion detection and location.

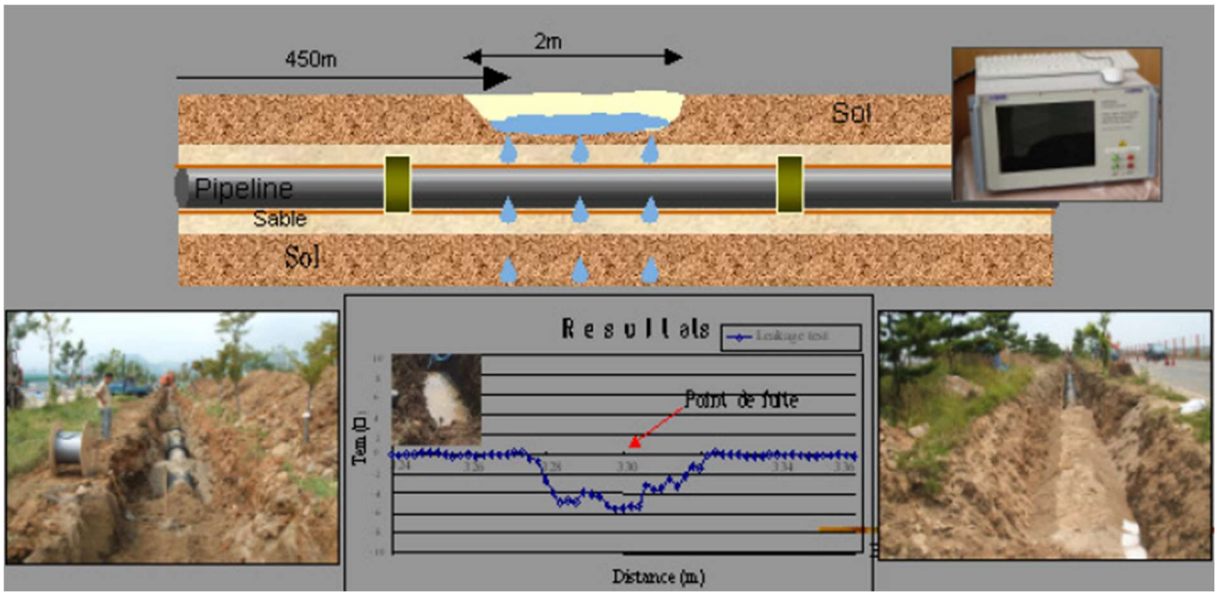


Another interesting application is the leakages detection and location.

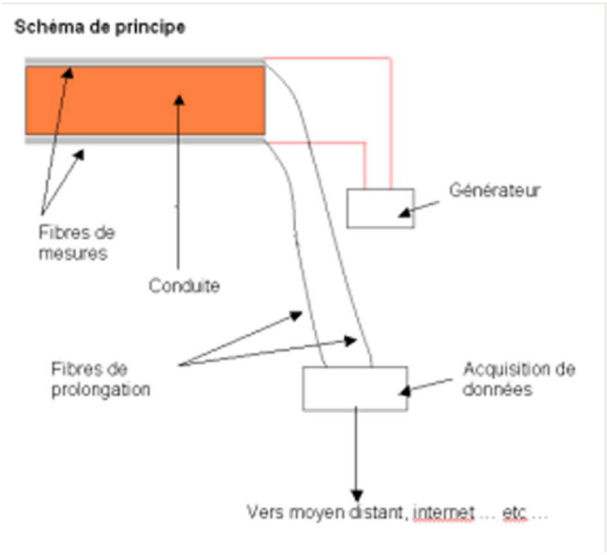


A fiber optic will sense ambient temperature in the ground. If a leak appears, the fluid will impact the fiber optic line with another temperature than the ambient one. Therefore detection and localization will be easy.

To dissociate, in case of rain, water infiltration from leakage, another fiber optic line is implemented on top of the pipe. If liquid stagnate on bottom fiber, the temperature seen will at some point, reach environmental temperature level and the difference will then be measured, in some case, frequency filtering may help leakage detection as the impact will create for short time a difference in temperature.



If, rare cases, fluid temperature and environment are suspected to be at exact same value, the trick will be to heat the fiber optic so a difference can be seen. Fiber optic line is then coated, under outside coating with an electrical conducting material. This coating will we powered with a generator and raise fiber optic cable to a determined temperature.



Distributed measurements Vs accuracy and spatial resolution

Bragg networks provide accurate positioning and good accuracy, data loggers can even sense dynamics signal allowing vibration measurements.

Distributed measurements (Brillouin and Raman) can reach +/- 1µm/m strength measurement accuracy and 1°C temperature accuracy (Brillouin) or +/- 0.1 °C (Raman).

Spatial accuracy is depending upon fiber optic length and datalogger technology. For long distance locating measurement at 0.5 meter or 1 meter is possible. Accuracy with this kind of spatial resolution remain excellent but all other points in between 0.5 or 1 meter will be sensed

as well, the accuracy will for these measurements not be as good but no phenomenon will escape.

The key point, as for any measurement, remain the sensor.

Knowledge in addition

No one can claim being expert on a wide number of subjects. Slope monitoring, dyke, bridges, tunnels or dams are different and one knows multifunction experts are very rare.

Geotechnical experts are analyzing the problem and pick up in instrumentation specialists drawer the tools that can be use.

The tools are sensing, conditioning, data logging, processing, transmitting, calculating, deciding.

We cannot pretend being skilled on each individual component of instrumentation but years of measurements impart us some knowledge that can help piling up the different parts of measuring solution to get the best results. Beside this we have a directory with contacts of specialists in different domains including instrumentation and geotechnics.

Our task is to add all needed knowledge to end up with successful answer.

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